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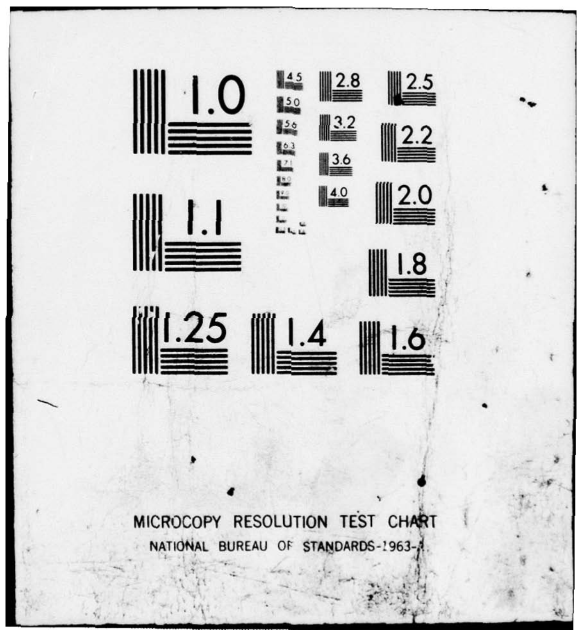
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REPORT No. 78008

ROYAL SIGNALS AND RADAR ESTABLISHMENT, CHRISTCHURCH.

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THE RSRE SATELLITE COMMUNICATIONS TEST FACILITY

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14 RSRE-78008

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12 15p.

PROCUREMENT EXECUTIVE, MINISTRY OF DEFENCE
RSRE
Christchurch, Dorset, England. BH23 4JB

11 March 1978

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RSRE REPORT NO 78008

THE RSRE SATELLITE COMMUNICATIONS TEST FACILITY

E H Thomas

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SUMMARY

This report contains a brief description of the RSRE satellite communications test facility at Steamer Point, Christchurch, Dorset, UK. Included is an explanation of the functions of the facility and a list of in-orbit measurement accuracies.

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ILLUSTRATIONS

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1 INTRODUCTION

The RSRE Satellite Communications Test Facility at Steamer Point, Christchurch essentially consists of a number of satellite communications Earth Stations connected on-line into a central Spacecraft Test Laboratory and from there into several R and D Laboratories. Construction of the main station with 40 ft aerial took place in early 1966, and on 16 June 1966 the equipment was used to monitor the historic injection into orbit of the first batch of US IDCSP satellites, the world's first satellites specifically designed for defence communications. A trans-Atlantic link between Christchurch and a US station in New Jersey, USA was in fact established on 18 June 1966. During the next three years the facility was considerably improved and carefully calibrated so that on 12 December 1969 in-orbit tests could start on the world's first geo-stationary defence communications satellite, UK spacecraft SKYNET I.

A detailed description of the facility as it was in April 1970 is given in an IEE publication[1]; this also contains papers detailing a number of the calibration procedures and some typical measurements. Since then the facility has been used for a wide variety of R and D purposes and for specialist support of MOD operations, and during the past eight years the number of stations has been increased and individual equipments much improved. This present report is intended to be a brief guide to the facility as it now exists.

2 FUNCTIONS OF THE FACILITY

The prime purpose of the facility is to support the development of MOD satellite communications systems. Aspects of this work are as follows:

a RESEARCH

The Establishment is engaged in studies of satcoms for various defence purposes, this work including trials.

b PROJECT SUPPORT

Support to MOD projects includes the testing of new types of Earth station equipments and sub-systems, and in-orbit testing of spacecraft.

c SPECIALIST SUPPORT TO SERVICE OPERATIONS

Such work includes studies of interference between various signals passing through spacecraft repeaters, diagnosis of fault conditions in the communications sub-systems of orbiting spacecraft, support of inter-operability trials, detailed measurement of transmissions from operational stations, measurement of spacecraft range and other tasks requiring special expertise.

3 FACILITY DESCRIPTION

The principal features of the facility are listed in Annex A. In broad terms they comprise:-

a an Earth station complex: a main 7/8 GHz station with 40 ft diameter aerial in 70 ft radome, a second SHF station with 17 ft aerial in 40 ft radome, a UHF station with 22 ft aerial and two small equipments with 6 ft aerials used for precision measurement of transmitted and received signal

levels. There is space for testing of R and D stations used in conjunction with the facility.

b a central measurement laboratory into which all the Earth stations are connected. This contains much precision equipment and is carefully engineered for high stability and flexibility. Calibrations are based on both UK and US standards. There are links with MOD for trials liaison and real-time relay of telemetry data.

c direct intermediate frequency connections from b above to adjacent laboratory buildings which are used for a variety of R and D projects.

d various special purpose test equipments and other support facilities, including a Commcen, station control room, stores, test library and support laboratories.

e a remote test installation consisting of 17 ft aerial and transponder equipment at distance 8 miles and height 400 ft on the Isle of Wight.

The area of the test facility is one having an acceptably low level of radio-frequency interference and a low horizon in all relevant directions. Although the transmitted power is high, it is directed out over the sea and there is no known health or other hazard. A local flying restriction provides for the safety of aircraft. The facility is manned by RSRE staff with a contractor's team in support.

The general layout is shown in Fig 1 and in schematic form in Fig 2. Views of some of the equipments are shown in Figs 3 to 8.

4 FACILITY PERFORMANCE

Special features of the facility are high reliability, stability and electrical performance. Over the years there have been a variety of improvements to the station equipments and these coupled with the use of radomes, air-conditioning, continuous (24 hour) running of critical sub-systems, disciplined maintenance and restrictions on access by staff to the individual units have resulted in the mean time between major failures (resulting in loss of trials time) being several months. There is high mechanical stability, for example a recalibration of a 6 ft antenna gain by a US team after a period of five years gave a value within 0.05 dB of the original value, this with a one sigma error of 0.2 dB. The 40 ft antenna gain has remained constant within 0.2 dB (1 sigma) over six years with a measurement accuracy of 0.17 dB and typically the whole receive system is electrically stable within 0.2 dB over a period of four hours.

Examples of electrical performance are as follows:

a Frequency stability of test signals:	1 part in 10^{11}
b Signal phase jitter (measured from transmitter input via microwave test loop to receiver output):	less than 10 degrees peak to peak

c No significant (measurable) in-band internally-generated spurious signals in the transmitters and receivers.

As an example, it has been possible to measure the leakage signals transmitted from the local oscillator on board a Skynet spacecraft, as transmitted at very low level by the spacecraft. The low phase jitter enables the equipment

to be used for determination of the phase stability of transmissions from remote stations, as relayed by a satellite. The spacecraft test laboratory has a variety of IF and baseband instrumentation including high-speed recorders for observation of transient phenomena.

The aim has always been to maintain complete and accurate calibrations, with proper analysis of errors. On occasion there have been completely independent calibrations by US teams using US standards and the results have been in good agreements with the RSRE values based on UK standards; for example one US calibration of the 6 ft standard receiving station, (which is used in turn to calibrate the larger stations) gave a value 0.15 dB different from the RSRE value, the one sigma errors of the US and UK calibrations being 0.19 dB and 0.15 dB respectively. Transmitter power can be varied over a range of 60 dB with an absolute accuracy (one sigma) of 0.12 dB.

The calibration and equipment measurement accuracies result in the values shown in Annex B for overall performance on satellite tests.

Operation of the station equipments is in a disciplined and formal manner. This is essential in order to avoid disruption of operational traffic passing through the satellites.

REFERENCE

1 IEE Conference Publication Number 63, April 1970. This contains seven papers relating to the RSRE facility.

ANNEX A: PRINCIPAL FEATURES OF THE TEST FACILITY AT STEAMER POINT

1 EARTH STATION COMPLEX

a 7/8 GHz station with 40 ft diameter aerial, 70 ft radome, 20 kW continuous wave transmitter, various receivers, control and support equipments. RF bandwidth will shortly be 0.5 GHz.

b 225/400 MHz stations with 22 ft diameter aerial, 1 kW cw transmitter, receivers and control equipments.

c 7/8 GHz station with 17 ft diameter aerial, 40 ft radome, 1 kW cw transmitter, receivers and control equipments.

d Two high-stability, accurately calibrated, microwave stations having 6 ft diameter aerials for precision signal-level measurements. One of these stations has a 1 kW transmitter.

e Space, hard-standing and all services for visiting transportable stations, R & D stations and an EHF station.

f Cable ducts between all stations and buildings.

g Main station control room with equipment, supporting workshops, heavy and light equipment stores, crew rest room and miscellaneous support equipments.

2 MAIN TEST INSTALLATION

a The Spacecraft Test Laboratory. This contains a substantial quantity of special test equipments in a carefully engineered and controlled electrical and physical environment. The test assemblies can be operated in a flexible manner and connected to any of the Earth stations.

b Support laboratories, calibration room, test library and communications room (Commcen).

c Computer for controlling tracking of 40 ft aerial and other on-line applications.

d Offices for operating staff, contractor's staff and visiting project staff, conference room, small kitchen and other usual services.

e Local tower for aerial calibration. At times a second temporary tower is erected in a nearby field.

3 R AND D LABORATORIES

a Laboratory building located close to the main test installation and connected to it at IF and baseband. This is used for modulation and earth station studies.

b Laboratory building located close to the main test installation and connected to it at IF and baseband, and also connected to external circuits. This is used for baseband system studies, for on-line (computer) studies of the characteristics of satcom links and for modulation equipments.

4 REMOTE TEST INSTALLATION ON ISLE OF WIGHT

ANNEX B: SOME IN-ORBIT TESTS

Parameter	Normal Test Method	Typical Value	Measurement Accuracy	Comment
			(rms error unless indicated otherwise)	
ERP towards RSRE	Fluxmeter comparison of signal power with that from standard source	47.5 dBm	0.25 dB	Needs clear sky. Corrections for atmospheric and polarisation loss. Tilt of spin-axis away from normal to orbital plane results in diurnal flux variation.
Polarisation of Spacecraft Flux	Plane polarised horn rotated to find max and min signal	1.7 dB	0.25 dB 7 deg	Errors refer to axial ratio and polarisation ellipse orientation. Results are mean for all angles of rotation of spacecraft polariser. Chief error due to multipath.
Repeater Transfer Characteristic	40 ft terminal used to measure spacecraft cw output as uplink power varied 50 dB	-93.5 dBm	0.4 dB	Needs clear sky. Error high because level at spacecraft receiver depends on gain, polar diagram, polarisation and orientation of spacecraft aerial. Value and error refer to input required to achieve cw output 3.0 dB below max. ('receiver sensitivity')
Receiver Noise Figure	Calculated from transfer characteristic	8 dB	0.8 dB	Relationship between characteristic and receiver pre-amplifier noise figure established experimentally prior to launch. *Note 180 deg K earth noise* received by spacecraft.
Bandwidth (3 dB) and Weak signal Suppression	Strong carrier kept at channel centre whilst weaker carrier (-10 dB) used to explore frequency response. Measurements made of returned weak signal relative to strong carrier	25 MHz	0.3 dB	Corrections for frequency response of terminal at moment of test. Chief uncertainty is exact ratio of the two up-link signals: (nominal 10 dB but actually varying for a number of reasons). Needs stable weather.
Imbalance between two nominally equal carriers injected into one channel	-	0.2 dB	0.2 dB	
Deviation of Beacon Carrier Frequency from nominal value (Approx 7.3 GHz)	Signal frequency measured using calibrated active notch filter	6 kHz	$\pm$ 8 Hz	Errors mostly arise in calculation of Doppler shift from range data.

Parameter	Normal Test Method	Typical Value	Measurement Accuracy	Comment
Separation of Beacon Sidebands from Carrier	-	120 kHz	± 3 Hz	
Beacon Modulation Index	Measure ratio of mean sideband power to carrier power	1.05 dB	± 5%	Ratio is $[Jo(m)/J_1(m)]^2$ where m is the index and Jo, J_1 are Bessel functions.
Signal Amplitude Modulation	High Speed ultra-violet recording. Also magnetic tape recording for spectral analysis by computer	0.5 dB	5%	Complex repeating patterns observed with frequencies approx 1-25 Hz. Spectral analysis yields considerable information on spacecraft condition: eg modulation at twice spin rate monitors rotation of spacecraft polariser.
Phase Modulation or Scintillation	Phase extracted from frequency-locked loop. Recording as above.	± 20 deg	4 deg	Sinusoidal phase variation observed at spacecraft spin rate but small high-frequency spacecraft phase scintillations partly masked by effects due to terminal oscillators and atmosphere.
Spurious Signal and Inter-modulation Product Measurements	Searches using spectrum analyser and narrow band receivers	-	0.4 to 0.8 dB	Numerous products generated when more than one carrier used to access spacecraft. Tables assist identification products.
Phase Frequency Response	Measurement of group delay. Phase change with frequency found by integration of results over appropriate frequency interval	± 10 deg over 20 MHz	20%	Results show classic 'S' curve but S/N ratio only marginally sufficient for measurements across wide channel. Corrections for terminal delay and spacecraft movement.

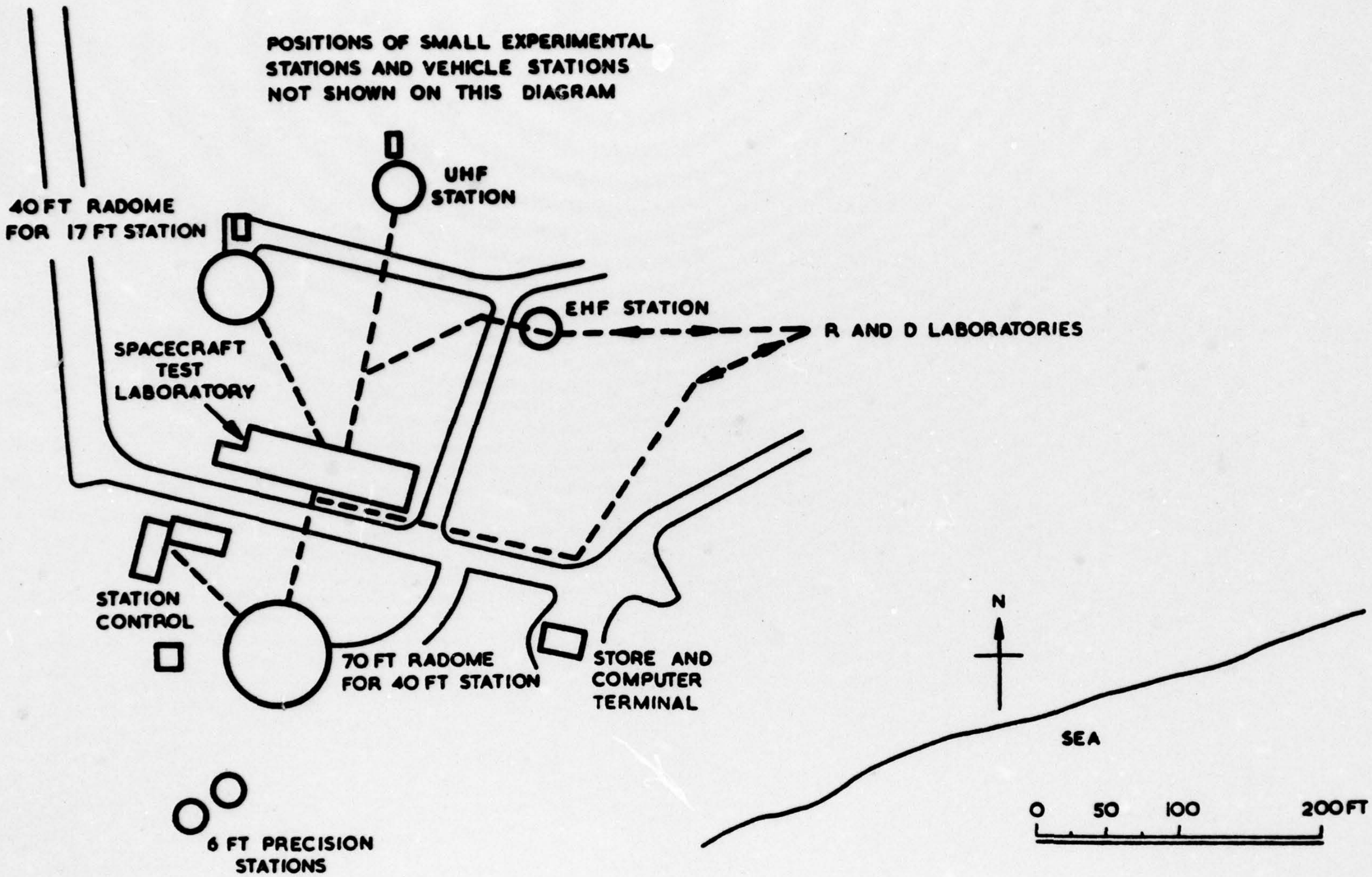

FIG.1 SATELLITE TEST FACILITY, STEAMER POINT, RSRE (CHRISTCHURCH) OUTLINE PLAN

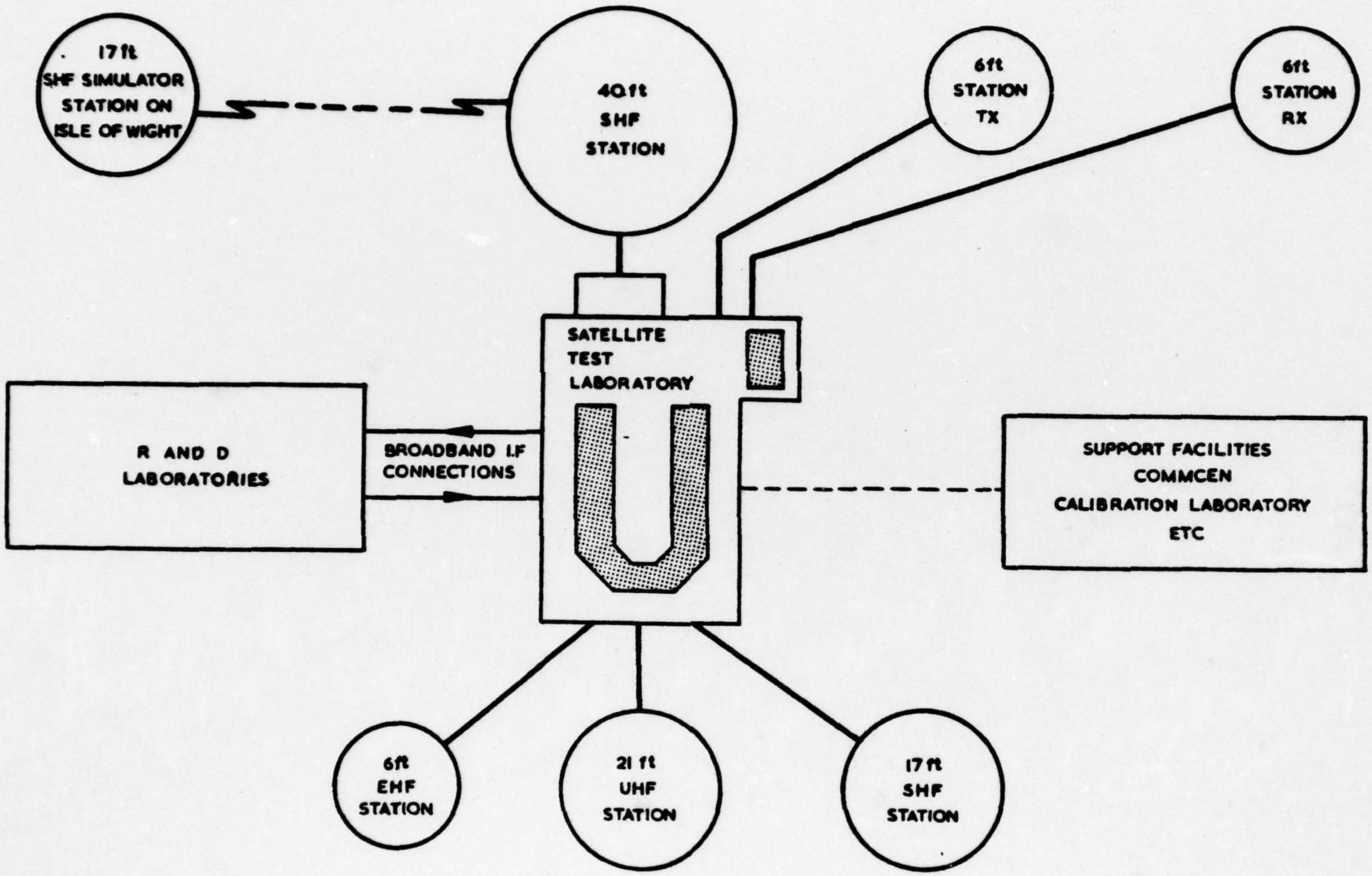

FIG.2 SATELLITE TEST FACILITY SIMPLIFIED PLAN

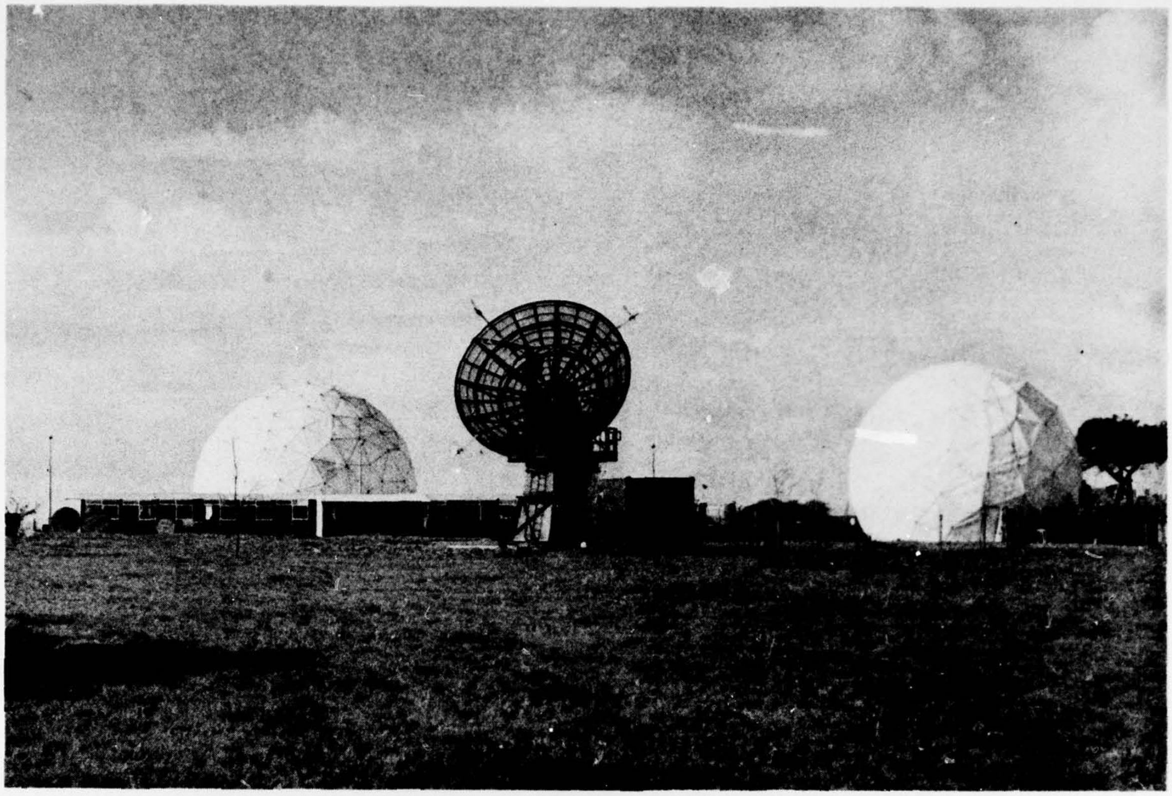

FIG 3   GENERAL VIEW FROM THE NORTH

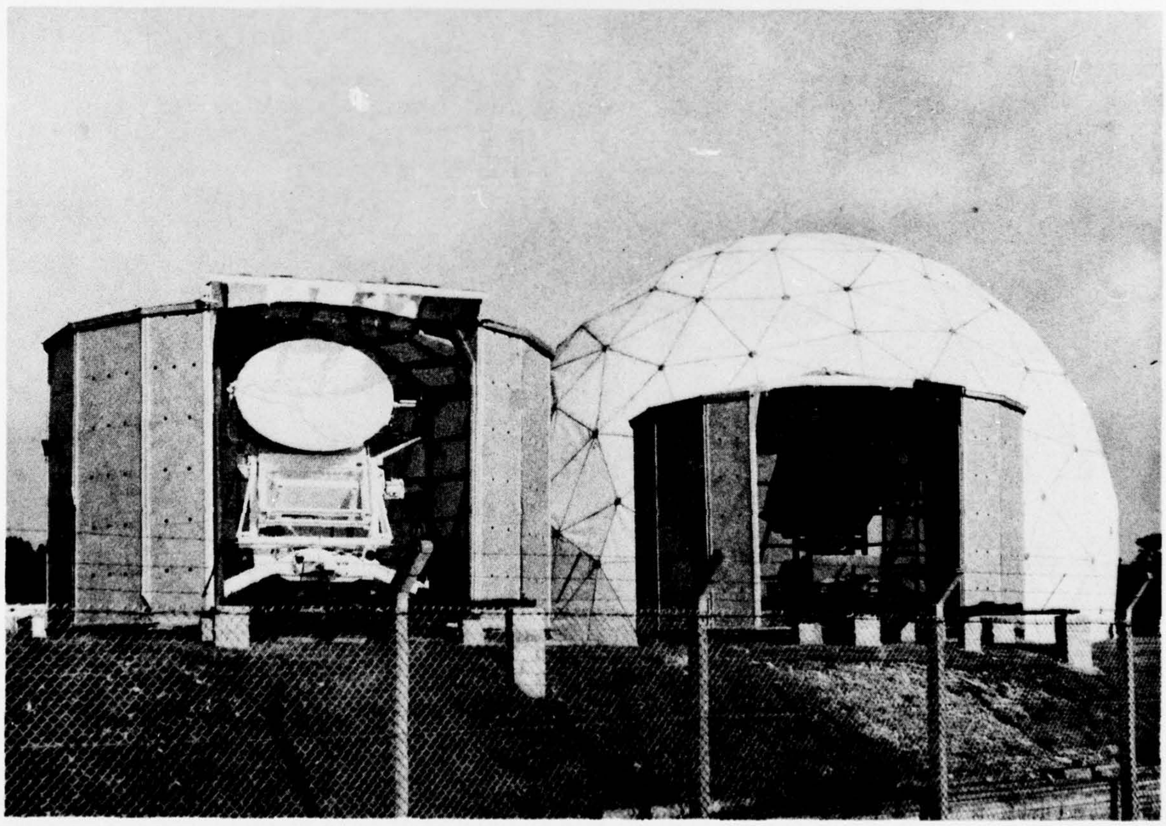

FIG 4   GENERAL VIEW FROM THE SOUTH

FIG 5 CONTROL ROOM FOR 40 FT EARTH STATION

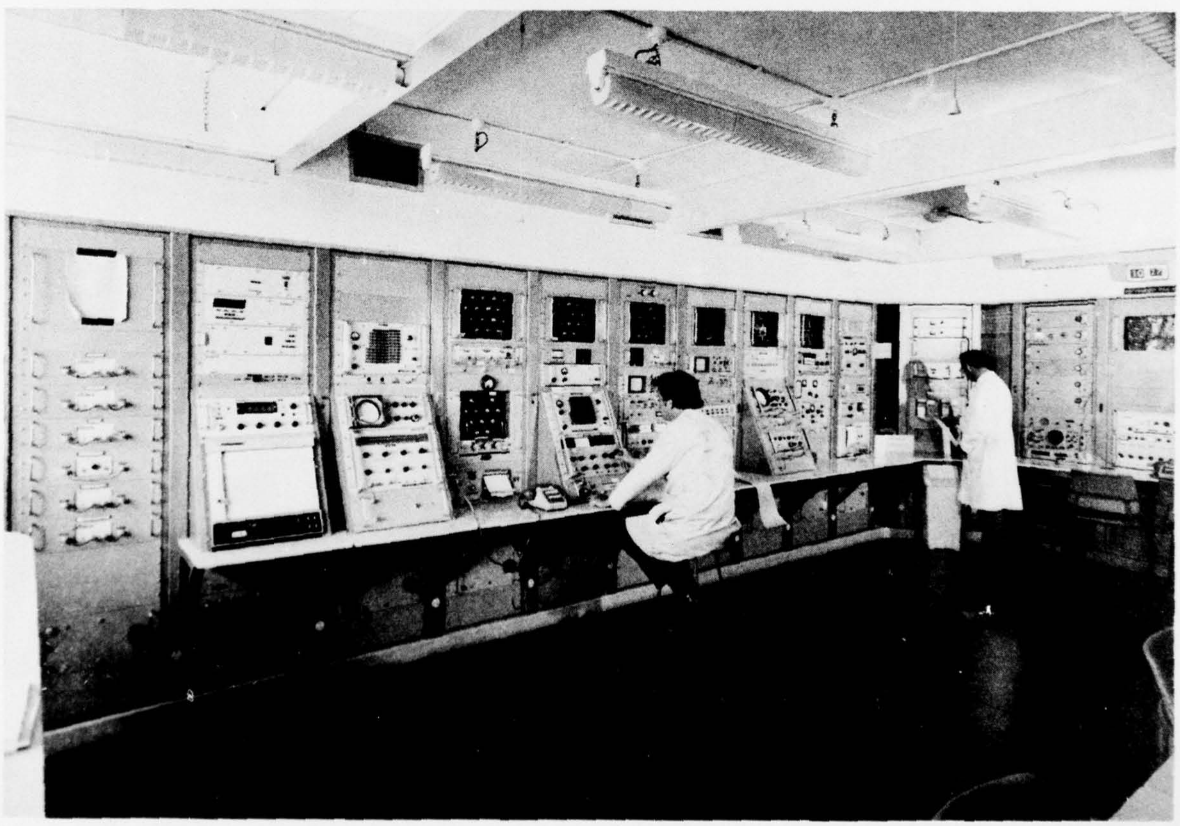

FIG 6 VIEW OF ONE PART OF THE SPACECRAFT TEST LABORATORY

FIG 7 SATELLITE SIMULATOR SITE ON ISLE OF WIGHT

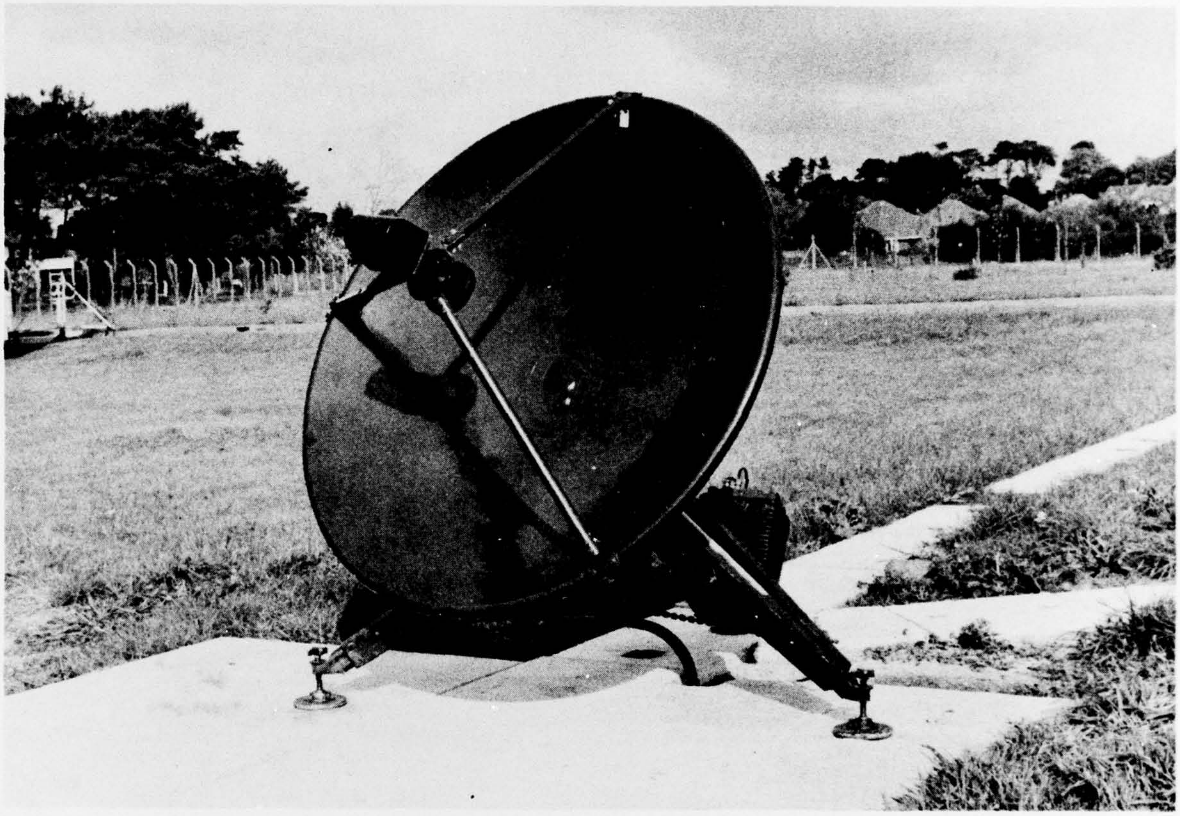

FIG 8 SMALL EXPERIMENTAL EARTH STATION

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1. DRIC Reference (if known)	2. Originator's Reference Report 78008	3. Agency Reference	4. Report Security Classification Unclass

5. Originator's Code (if known)	6. Originator (Corporate Author) Name and Location RSRE (C)
5a. Sponsoring Agency's Code (if known)	6a. Sponsoring Agency (Contract Authority) Name and Location

7. Title

The RSRE Satellite Communications Test Facility

7a. Title in Foreign Language (in the case of translations)

7b. Presented at (for conference papers) Title, place and date of conference

8. Author 1 Surname, initials Thomas E H	9(a) Author 2	9(b) Authors 3,4...	10. Date	pp. ref.

11. Contract Number	12. Period	13. Project	14. Other Reference

15. Distribution statement

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Descriptors (or keywords)

Satellites Communications Testing

continue on separate piece of paper

Abstract

This report contains a brief description of the RSRE satellite communications test facility at Steamer Point, Christchurch, Dorset, UK. Included is an explanation of the functions of the facility and a list of in-orbit measurement accuracies.